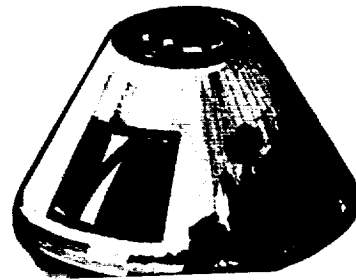


# Preliminary Data

## from studies of Fire Retardant Materials



(NASA-TM-108665) PRELIMINARY DATA  
FROM STUDIES OF FIRE RETARDANT  
MATERIALS (NASA) 39 p

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INTRODUCTORY REMARKS ON THE  
DEVELOPMENT OF FIRE PROTECTIVE SYSTEMS

by Glen Goodwin  
Chief, Thermo- and Gas-Dynamics Division

Ames Research Center, NASA, Moffett Field, Calif.

The work at Ames Research Center on fire protection and fire suppression that will be reported in this meeting was started in September of 1967, and was motivated both by the tragic Apollo fire and the realization that the principles utilized in the protection of entry vehicles from aerodynamic heating could be exploited to give some measure of protection from both spacecraft and aircraft fires. Two developments will be discussed and described: the use of a low-density polyurethane-based foam material to suppress a fire and to provide protection for the structure of an aircraft or spacecraft, and the use of an intumescent paint which, when activated by the heat of a fire, reacts to form a thick, low-density, polymeric coating that protects the substructure upon which it has been applied by virtue of its extremely low thermal conductivity and by the release of water vapor during the intumescent reaction.

The basic chemistry upon which these protective mechanisms depend will be described, the preliminary material formulation and screening tests will be discussed, process and material specifications will be presented, and, finally, the limited evaluation tests in fuel fires that have been conducted in the last few weeks will be presented.

We wish to emphasize that this meeting is a progress report on our development program and by no means should be taken as a description of fully developed and evaluated methods of fire suppression and fire protection; however, the program is far enough along to show some promise of affording one solution to this important problem and hopefully will inspire some ideas from you which may help us in translating this research work into useful products that can be applied to aircraft, spacecraft, or other vehicles and structures subjected to the ravages of fire.

In this program we have laid down certain ground rules which hopefully will avoid the normal long lead times between the generation of an idea and the production of a final useful product so common in many research and development projects. First, we have gathered a team of specialists from a number of the organizational segments at this Research Center in order that special skills could be brought to bear on the problem in all of the disciplines needed for its development. Secondly, we have stipulated that only commercially available materials are to be used in this first phase of the program to avoid the time delays in inventing and producing new material systems. This decision has, of course, resulted in a product

which we feel can be much improved with additional work, but it has resulted in very rapid progress by our ordinary standards. In addition, we have stipulated that these polyurethane foam systems and intumescent paints must be easily applied to existing vehicles in the field or in a base area.

It is against these somewhat restrictive rules, imposed to save development time, that this program should be judged. We are sure that improvements in all of these systems will be made as we proceed. Again we emphasize that this discussion today is a progress report, and we hope that by the summer of 1968 we will be in a position to describe to you the end of the first phase of this work.

Before introducing the various specialists who will describe their own phases of this program in detail, I will briefly discuss the basic ideas behind both the polyurethane foam system and the intumescent paint and indicate how our research in thermal protection of entry vehicles has contributed importantly to this program.

The protection of any structure, be it an entry vehicle or an aircraft, against damage by heat can be accomplished by the same basic protective mechanisms. It matters little what the source of the heat is. Heat generated by fire, by a hot gas cap surrounding an entry vehicle, or by an explosion have much in common. In order to damage a structure, heat must be carried to the structure by either free or forced convection or by radiation. Therefore, any or all of the heat-protective mechanisms can, in principle, be utilized to afford protection.

The simplest form of heat protection is to provide a high resistance to heat flow between the heat source and the structure. This principle has been utilized in both the polyurethane foam system and the intumescent paint. Both of these systems have very low thermal conductivity by virtue of their low density and closed-cell construction which provide a high resistance to heat flow. Another important mechanism, often overlooked in fire protection systems but widely utilized in spacecraft thermal-protection systems, is the release of a gas from the thermal-protective material when it is subjected to a heat load. These gases serve to protect the system in two important ways. First, the gases near the surface flow against the incoming heat, thus impeding the flow of heat to the surface. For example, in a spacecraft being protected against reentry heating, these gases can block nearly all of the convective heat flow. Second, in protecting against a fuel fire, these gases can be made rich in halogens which can chemically scavenge the chain carriers by which fuel flames are propagated and hence serve as fire-extinguishing agents. This principle has been utilized in the polyurethane systems. In the case of the intumescent coatings, the

gas given off is largely water vapor which also serves as a fire extinguishing agent.

Another mechanism that affords protection against fires is the production of a char resulting from the action of heat upon these materials. If a char can be formed having low thermal conductivity and high oxidation resistance, this char will not only afford protection by virtue of its low thermal conductivity, but its surface will reach a high temperature and thus will be capable of re-radiating a large fraction of the incident heat load. The mechanism is utilized in both of the systems that we are developing. In the polyurethane foam material, polyvinylchloride has been added which when heated causes the polyurethane to form a stable, tough char of low thermal conductivity. This idea came directly from our work on thermal protection systems for reentry vehicles in which we have learned how chars are formed and how to produce materials that do form chars. In particular, the polymeric material formed by the action of heat upon the intumescent coating is extremely oxidation resistant and appears from results of limited tests to be stable in air up to temperatures of about 1000°F. Thus, both of these material systems utilize the protective mechanism provided by low thermal conductivity of stable chars.

This emphasizes an important point about the systems we will be discussing; that is, these systems react to an applied heat load to provide a number of protective mechanisms which are not present in a system that does not respond to a fire. Thus, these are not passive systems, but rather are dynamic systems which respond to provide protection when exposed to a fire.

With this introduction, let us now proceed with the technical presentations.

# FOAM PROPERTIES DESIRED FOR FUEL-FIRE SUSPENSION

## IMPACT IGNITION

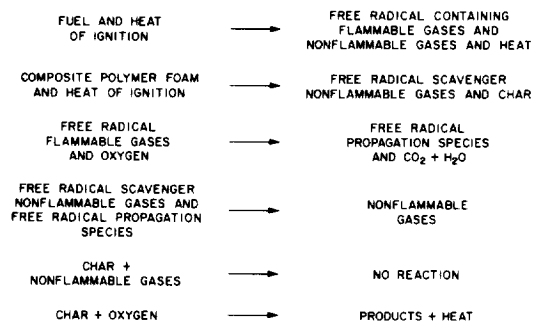
- LOW DENSITY-VOID-FILLING CAPACITY TO ELIMINATE ATOMIZATION OF COMBUSTIBLE LIQUIDS
- CLOSED CELL FOAM STRUCTURE WITH SELF SEALING SKIN TO PREVENT OUT-POURING OF COMBUSTIBLE LIQUIDS
- PYROLYSIS AT LOW TEMPERATURE, AT HIGH RATE TO GIVE HYDROGEN BROMIDE, HYDROGEN CHLORIDE OR HYDROGEN FLUORIDE AND FREE RADICALS TO INHIBIT IGNITION

## SUSTAINED FIRE PROTECTION

- DECOMPOSES AT MODERATE RATE TO GIVE LOW MOLECULAR WEIGHT SPECIES TO SUPPRESS FLAMES
- EXCELLENT LOW HEATING RATE ABLATION EFFICIENCY TO MINIMIZE HEAT TRANSFER TO AIRCRAFT STRUCTURES

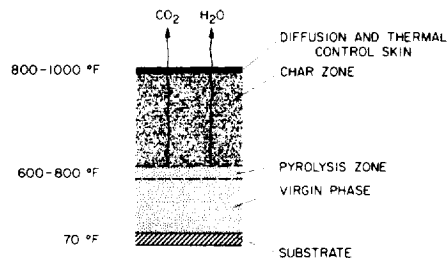
Outline of physical and chemical properties desired for development of idealized fire suppressant foam system, and coupling of properties needed to accomplish both ignition and ablative material protection.

# MECHANISMS FOR FIRE PROPAGATION AND QUENCHING



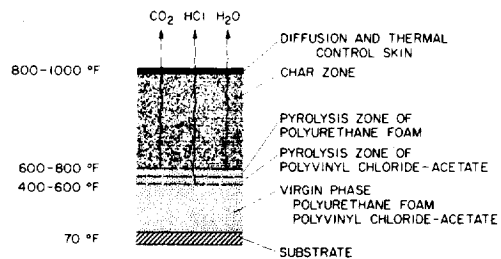
Outline of kinds of thermochemical reactions about which one must be concerned to understand fire protection mechanisms.

RESPONSE OF THE UNMODIFIED POLYURETHANE FOAM TO  
THE HEATING INPUT OF A FUEL FIRE  
(TYPE 5-0)



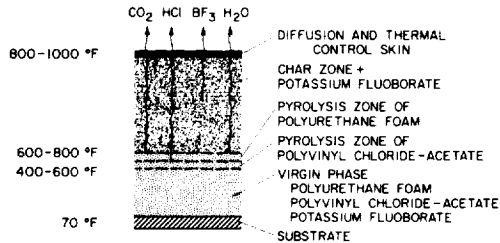
Pictorial presentation of the mechanism of fire protection, showing the pyrolysis of an unmodified polymeric char-forming low density foam.

RESPONSE OF POLYVINYL CHLORIDE-ACETATE MODIFIED  
POLYURETHANE FOAM TO THE HEATING INPUT OF A FUEL FIRE  
(TYPE 5D)



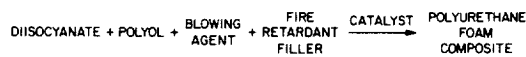
Pictorial presentation of the mechanism of fire protection, showing the interaction of polyvinyl halide additive to increase char yield and inject hydrogen halide into flame front.

RESPONSE OF POTASSIUM FLUOBORATE + POLYVINYL  
CHLORIDE-ACETATE MODIFIED POLYURETHANE FOAM TO THE  
HEATING INPUT OF A FUEL FIRE  
(TYPE 51)



Pictorial presentation of the mechanism of foam-fire interaction by adding the action of an inorganic salt,  $\text{KBF}_4$ , to the foam.

POLYURETHANE COMPOSITE FOAM PREPARATION  
AMBIENT TEMPERATURE FOAM-IN-PLACE COMPOSITE



POLYURETHANE FOAM COMPOSITE  
TYPICAL MATERIALS USED:

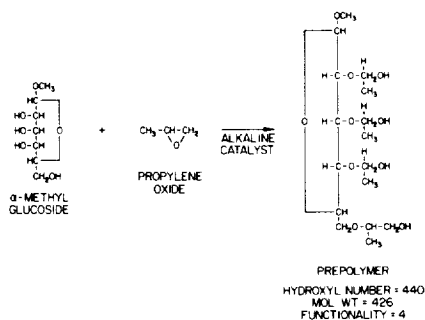
- POLYOL (PREPOLYMER)
- DIISOCYANATE (COREACTANT FOR POLYURETHANE)
- BLOWING AGENT (VOLATILE HALOGENATED HYDROCARBON)
- FIRE RETARDANT (HALOGENATED ORGANIC OR INORGANIC MATERIAL)
- CATALYST

TYPICAL PROPERTIES

- FLEXIBLE OR RIGID
- DENSITY 1.5 TO 3 lb/ft<sup>3</sup>
- NON-BURNING OR SELF-EXTINGUISHING (DM 192)

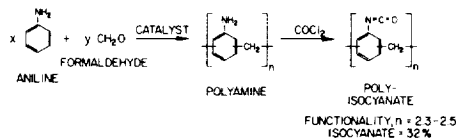
General approach to the formulation of a composite polyurethane foam to effect fire protection, including components and reactions.

STARTING MATERIALS FOR  
POLYURETHANE FOAM SYSTEMS  
INTERMEDIATE POLYOL FORMATION



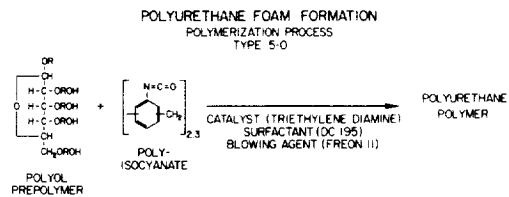
Structure and method of preparation of specific polyol used in the formulation of 5-series foams.

PREPARATION OF POLYCYCLIC AROMATIC ISOCYANATE  
INTERMEDIATE ISOCYANATE FORMATION

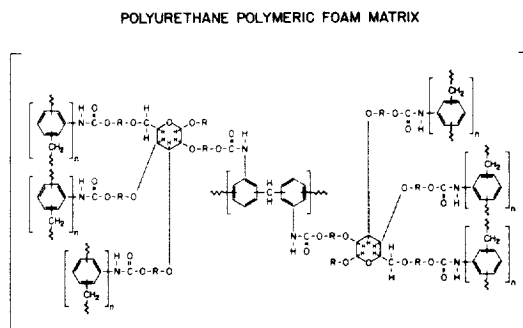


Specific aromatic polycyclic isocyanate selected for the development of 5-series foams.



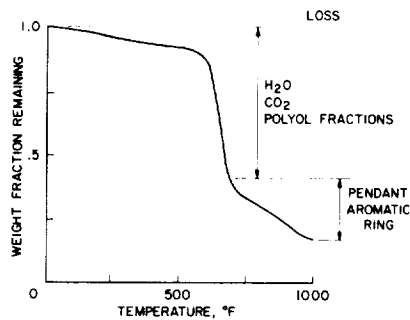


Polymerization and foaming process for 5-series foams from co-reactants.

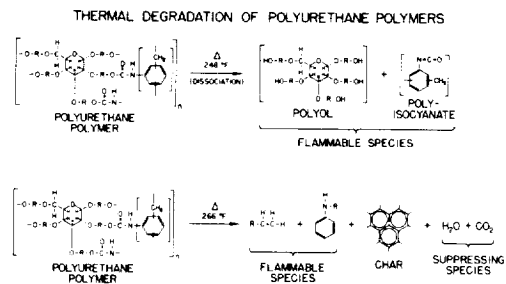


General chemical structure of the foam matrix of the unmodified 5-series foams. The structural features of importance to thermochemical processes encountered with this foam are shown.

TGA OF UNMODIFIED POLYURETHANE FOAM  
(TYPE 5-0)  
(5.4° F/min IN N<sub>2</sub>)

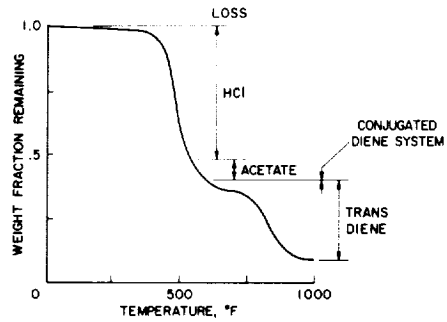


Thermochemical behavior of unmodified foam determined from thermogravimetric analysis. The effect of time-temperature history, on both the weight remaining and volatile species lost, is indicated.



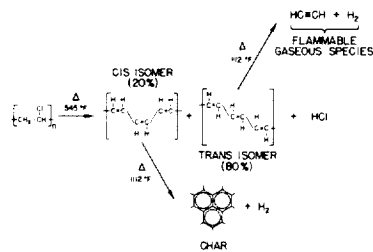
Proposed thermochemical reactions of unmodified polyurethane foams.

TGA OF POLYVINYL CHLORIDE ACETATE COPOLYMER  
(5.4 °F/min IN N<sub>2</sub>)



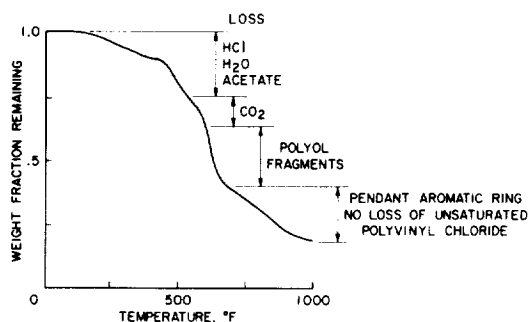
Thermochemical behavior of virgin polyvinylchloride-acetate under thermogravimetric conditions.

THERMO-CHEMICAL ACTION OF POLYVINYL CHLORIDE



Proposed thermochemical reactions of virgin polyvinylchloride acetate.  
Nature of volatile species is indicated.

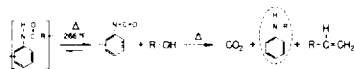
TGA OF POLYVINYL CHLORIDE MODIFIED POLYURETHANE FOAM  
(TYPE 5D)  
(5.4° F/min IN N<sub>2</sub>)



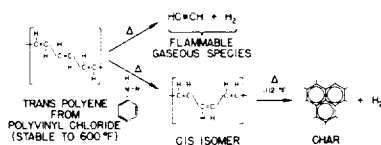
Thermochemical interactions of polyurethane foam and polyvinylchloride acetate copolymer determined from a thermogram.

#### THERMO-CHEMICAL ACTION OF THE POLYURETHANE

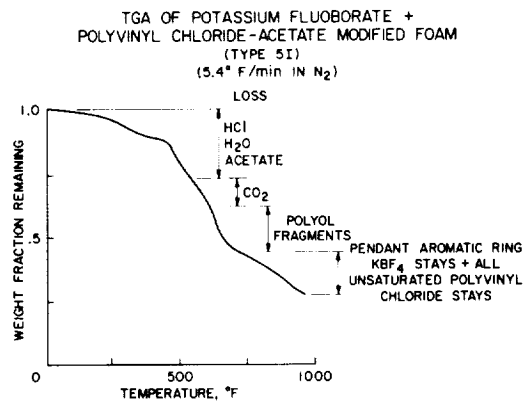
##### THERMAL DECOMPOSITION OF THE POLYURETHANE



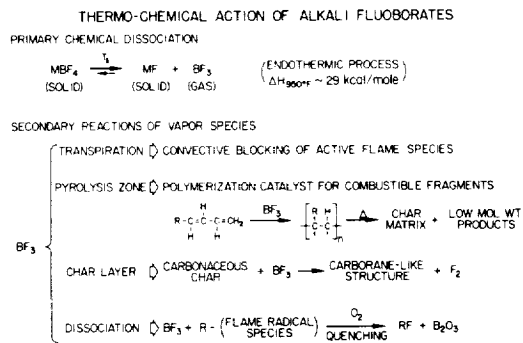
##### STABILIZATION OF THE ALKYL HALIDE RESIDUE



Proposed thermochemical interactions of polyurethane degradation products and those of the polyvinylchloride acetate copolymer.



Thermogram of the composite fire suppressant foam 5-I, indicating action of the added alkali fluoborate.



Thermochemical interactions of the alkali fluoborates with other components of composite foam of the 5-I type.

THERMO-CHEMICAL ANALYSIS OF STARTING MATERIALS FOR  
COMPOSITE FOAMS

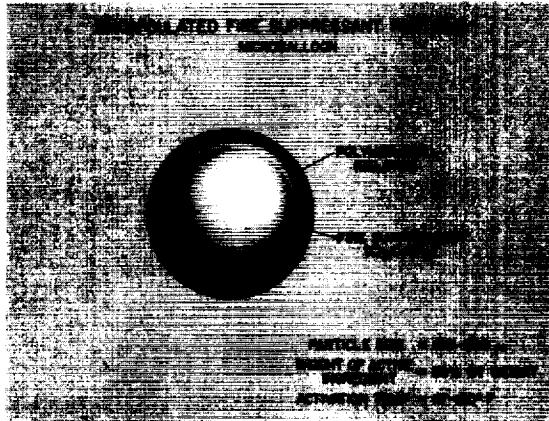
MATERIAL	TEMP. RANGE, °F		TRANSPIRING GASES	% RESIDUE		REMARKS
	INITIAL	FINAL		CALCULATED	MEASURED	
VMCH 88/12	392	545	HCl	48.8	48.8	80/20 RATIO OF TRANS TO CIS POLYMER IN VMCH
	545	599	[CH <sub>3</sub> CO OH]	3.5	—	
	599	1112	UNSATURATED SPECIES [3 C <sub>2</sub> H <sub>2</sub> + H <sub>2</sub> ]	8.5	8.5	ONLY CIS FORMS CHAR
5-0 POLY- URETHANE UNFILLED	572	707	CO <sub>2</sub> + H <sub>2</sub> O + POLYOL FRAGMENTS	42.4	41.6	FIRE SUPPRESSANT SPECIES FROM POLYURETHANE
	707	1112	AMINES + UNSATURATED HYDROCARBONS	15.5	16.45	ONLY FRAGMENT WHICH REMAINS IS 2 OUT OF 4 AROMATIC RINGS

Summary of results obtained from thermogravimetric analysis of polyvinylchloride acetate copolymer (VMCH), and unmodified 5-0 foam, showing agreement between expected and measured fraction of gaseous products obtained during pyrolysis.

THERMO-CHEMICAL ANALYSIS OF COMPOSITE FOAMS

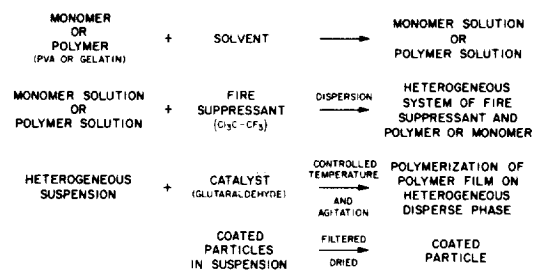
MATERIAL	TEMP. RANGE, °F		TRANSPIRING GASES	% RESIDUE		REMARKS
	INITIAL	FINAL		CALCULATED	MEASURED	
5D	455	545	HCl + 6 H <sub>2</sub> O + ACETATE	16.02	16.6	
	545	608	{ 4 CO <sub>2</sub> 3 CO <sub>2</sub>	16.6 11.9	12.4 12.4	
	608	689	HYDROCARBON FRAGMENTS C <sub>18</sub> H <sub>22</sub>	24.3	26.6	
	689	1112	AMINE FRAGMENTS C <sub>14</sub> H <sub>28</sub> N <sub>4</sub>	17.9	20.0	
5I	446	545	HCl + 6 H <sub>2</sub> O + ACETATE	14.82	16.0	
	545	608	4 CO <sub>2</sub>	15.2	13.5	
	608	716	HYDROCARBON FRAGMENTS	21.5	20.6	
	716	1112	AMINE FRAGMENTS	26.4	29.4	

Summary of results obtained from thermogravimetric analysis of composite foams 5-D and 5-I, showing agreement between expected and measured fraction of gaseous products obtained during pyrolysis.



General description and properties of encapsulated fire retardant as used to prepare foams of the 5-AF type.

#### FABRICATION PROCESS FOR ENCAPSULATED FIRE SUPPRESSANT



Outline of steps involved in forming microballoon containing fire suppressant encapsulant.

# FIRE SUPPRESSANT FOAM

## 5-0 COMPOSITION

	PARTS
POLYMERIC POLY-ISOCYANATE (MONDUR MR)	100
METHYL GLUCOSIDE POLYOL (PLURACOL 201)	65
TRICHLORO FLUOROMETHANE (FREON 11) (bp 78.8° F)	37
SURFACTANT (DC 195)	.9
CATALYST (TRIETHYLENE DIAMINE, DABCO 33 LV)	1.4

Composition of type 5-0 polyurethane foam. Amounts are given in parts by weight.

## FIRE SUPPRESSANT FOAM COMPOSITION

COMPOSITION, PARTS		
5I	5AF	5AH
16.5	16.5	16.5
16.5	16.5	16.5
16.5	16.5	16.5
	16.5	16.5
	16.5	16.5

POTASSIUM FLUOBORATE (92% < 100μ)

POLYVINYL CHLORIDE (VMCH) (83% < 250μ)

FREON 113 MICROBALLOONS (bp 117° F) (100-300μ)

PHOSPHONATE ESTER (FYROL 6)

Fire-suppressant additives used in 5-I, 5-AF, and 5-AH foams. These materials are added to basic 5-0 constituents.



# SUMMARY OF PROPERTIES

5-O	5I	5AF	5AH	
45.0	49.7	53.4	68.2	CREAM TIME, sec
95	250	332	902	RISE TIME, sec
219	352	459	1479	CURE TIME, sec
1.94	2.51	2.23	2.27	DENSITY, lb/ft <sup>3</sup>
4.3	3.3	4.5	5.3	POROSITY, %, H <sub>2</sub> O
34.2	30.5	21.2	19.2	COMPRESSIVE STRENGTH, psi
.0007	.0014	.0039	.0038	LOAD DEFORMATION, in/lb
52.6	63.3	42.9	40.2	% RETURN
9.2	9.1	7.3	6.9	IMPACT STRENGTH, in/lb
11.3	8.8	16.3	26.5	DIMENSIONAL STABILITY % VOL INCREASE AT 284° F
3.34	3.7	5.0	4.6	FUEL ABSORPTION, JP-4 VOL %, 16 hrs AT 70° F
NONE	NONE	NONE	NONE	WICKING

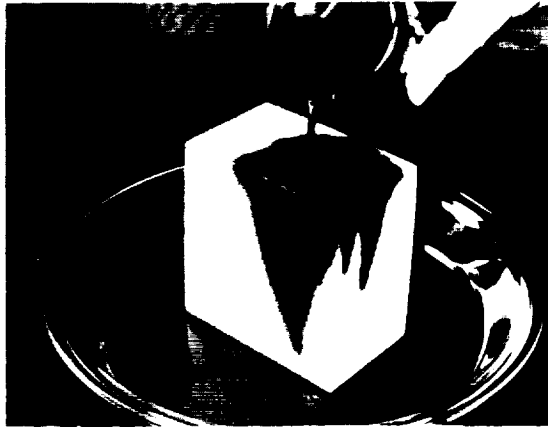
Summary of measurements made on 5-O, 5-I, 5-AF, and 5-AH foams. The values given are averages of 10 batches.

# PROPERTIES OF MACHINE MIX FOAM

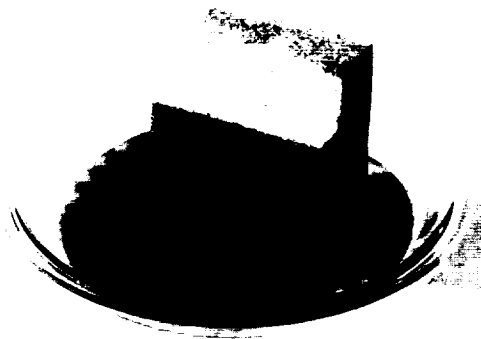
## 5I COMPOSITION

	MACHINE MIX	HAND MIX
DENSITY, lb/ft <sup>3</sup>	2.01	2.51
POROSITY, %	3.5	3.3
COMPRESSIVE STRENGTH, psi	21.1	30.5
IMPACT STRENGTH, in/lb	5.5	9.1
FUEL ABSORPTION, JP-4 VOL %, 16 hrs AT 70° F	3.5	3.7

Comparison of properties of machine and hand mixed 5-I foam.



Dyed JP-4 fuel being poured on 5-I foam.



Cross section of 5-I foam sample after exposure to JP-4 fuel. Note absence of wicking action, indicating closed cell structure of the foam.



Illustration of the effect of surfactant on cell structure. Sample on left had no surfactant; that on right, 0.5% surfactant.



Photomicrograph of surface of 5-I polyurethane foam.

#### FUTURE WORK

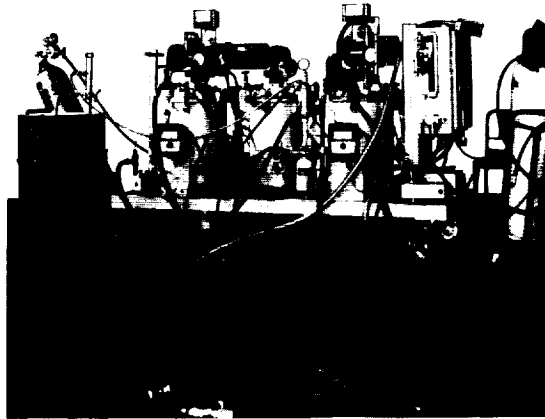
- PROPERTY VARIATION WITH COMPOSITION CHANGE
- OPTIMIZE FORMULATIONS
- SET UP RAW MATERIAL SPECS
- ESTABLISH PRODUCT SPECS

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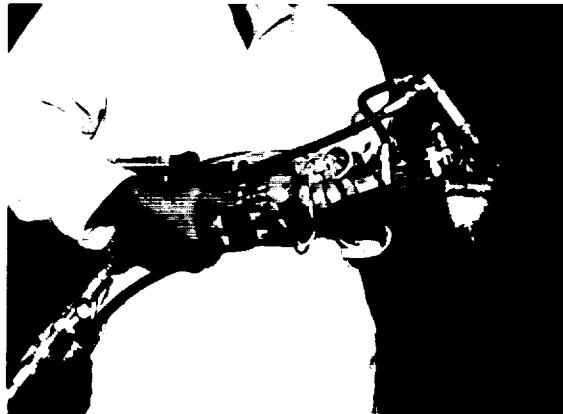


The A. Kraft Company "hydrosponder," which mixes and dispenses two-component foams with precise mixture ratio control. It is a batch-process unit, without recirculation capability, for small quantity pour applications.

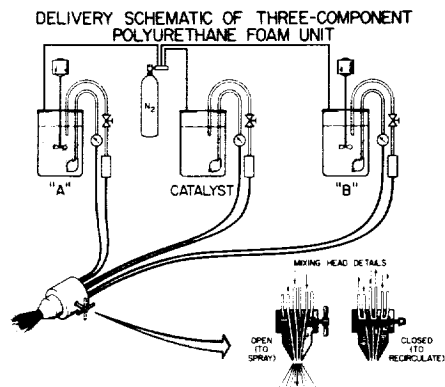
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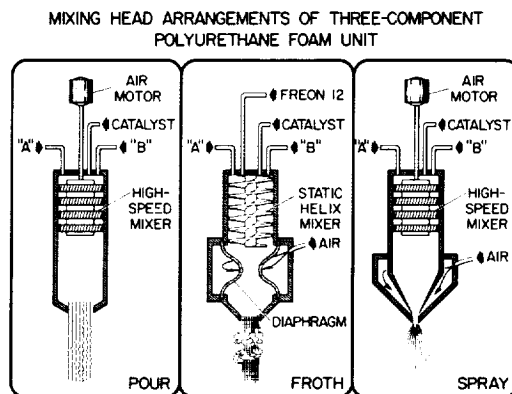
The Martin Sweets Company three-component pumping and metering unit. Ten-gallon tanks are fitted with submerged positive displacement pumps, driven through variable-ratio transmissions.



The Martin Sweets Company mixing head has pour, froth and spray capability. Recirculation feature and requirements for air, blowing agent, and solvent flush account for large number of delivery lines.

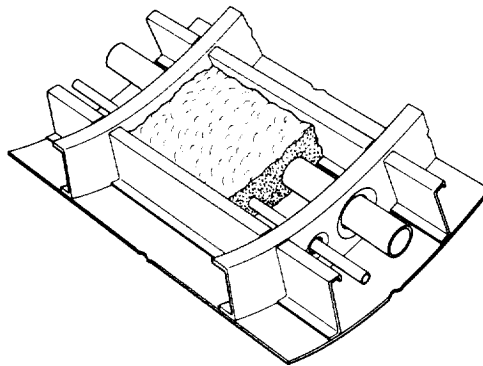


Sweets foam unit schematic showing recirculation lines and associated pressure-balancing hardware. Tank "A" normally contains isocyanate, tank "B" the polyol and salts, and tank "C" the catalyst. Air and blowing agent lines are omitted. Nitrogen provides inerting blanket for components in the tanks.



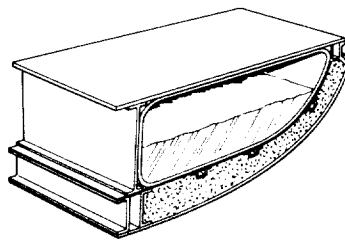
Diagrammatic representation of mixing head arrangements for the three application modes possible with the Sweets foam unit.

TYPICAL SPRAY APPLICATION



Typical spray application.

TYPICAL POUR OR FROTH IN PLACE APPLICATION



Typical pour or froth in place application.

TYPICAL PREMOLDED PANEL APPLICATION

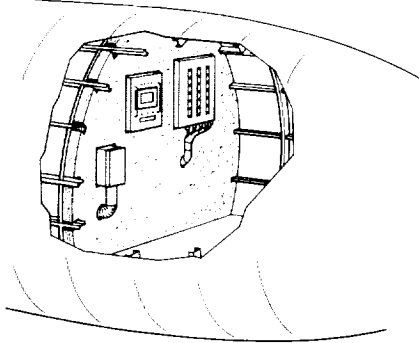


Illustration of use of pre-molded panels, glued or fastened in place.

TYPICAL BLOWN IN PREFORMED "DRY" FOAM APPLICATION

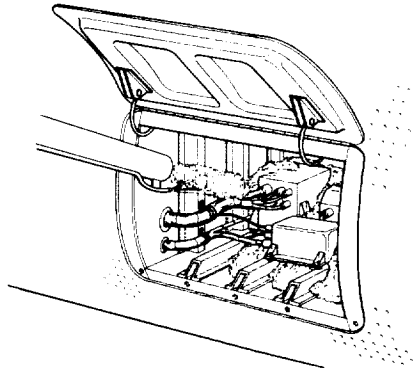
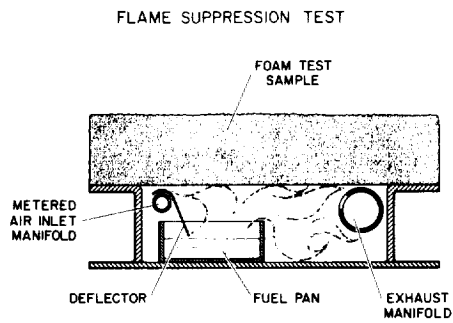
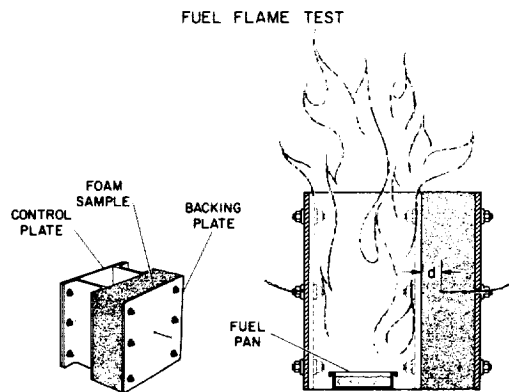


Illustration of blow-in technique, wherein pre-molded foam pieces are blown into cavities. Coincident glue spray lightly bonds the pieces but permits easy removal for accessibility.

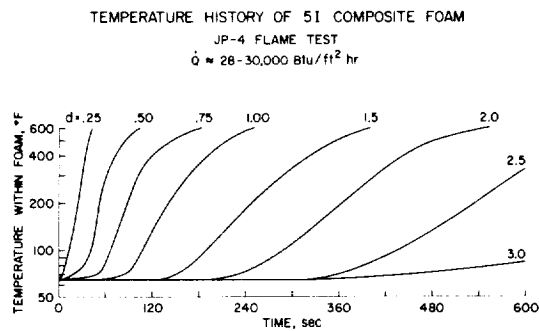




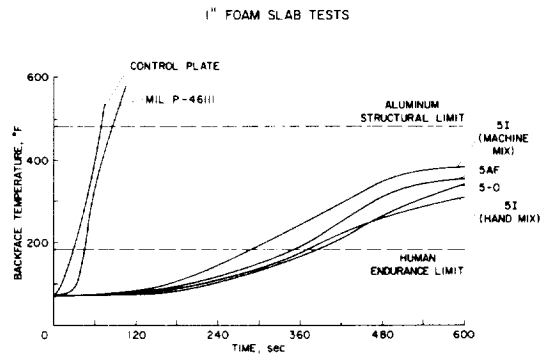
Test apparatus to demonstrate the suppression and quenching properties of the composite foams on a controlled JP-4 fuel fire.



Test apparatus to demonstrate the thermal protection properties of the composite foams when subjected to large JP-4 fuel fires.

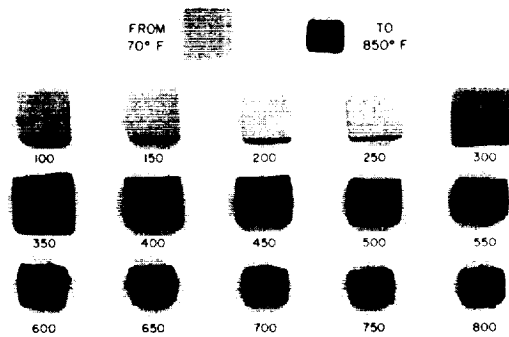


Temperature histories at various depths in a thick slab of 5-I foam, illustrating insulating qualities of foam.



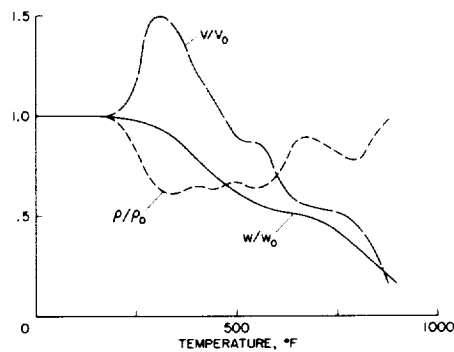
Comparison of protection afforded an aluminum alloy plate (1/8" thick 2024-T4) by 1-inch thick slabs of various composite foam systems and MILP-46111 foam.

COLOR/SIZE VARIATION OF 5-I COMPOSITE FOAM  
WITH TEMPERATURE



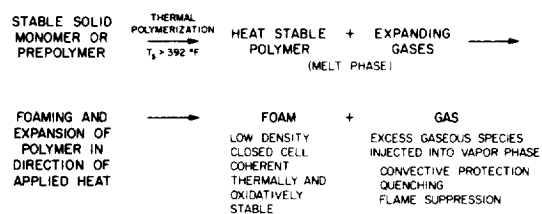
Variation of color and size of 1-inch cubes of 5-I composite foam from 70°F to 850°F. Samples were soaked at the various temperature levels for at least 20 minutes.

VOLUME/WEIGHT VARIATION FOR 5-I COMPOSITE FOAM



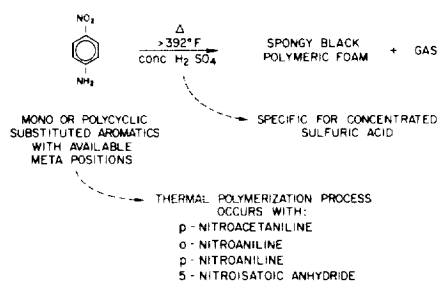
Variation of volume, weight and density ratios of 5-I foam as obtained from samples of the color-size comparison chart of the previous figure.

# GENERAL SEQUENCE OF REACTIONS PRODUCING INTUMESCENCE



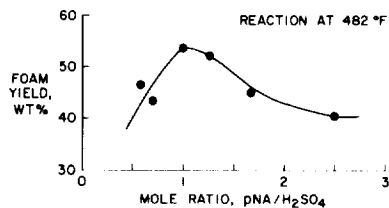
Idealized scheme for obtaining controlled intumescence.

## INTUMESCENT REACTIONS OF NITRO SUBSTITUTED AROMATIC AMINES



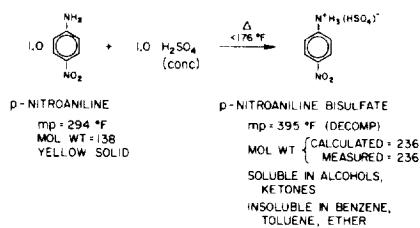
General behavior of nitro-aromatic amines and sulfuric acid with heating.

EFFECT OF p-NITROANILINE/H<sub>2</sub>SO<sub>4</sub> RATIO  
ON FOAM YIELD

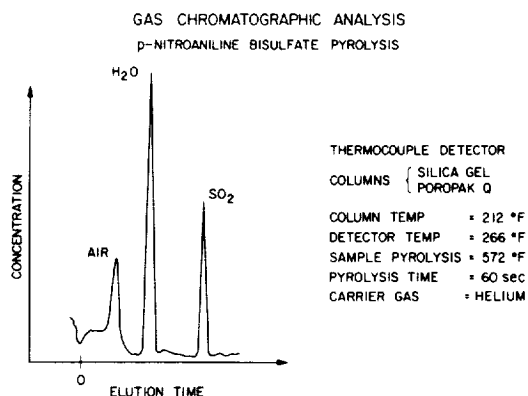


Determination of the basic stoichiometry of the reaction between sulfuric acid and p-nitroaniline.

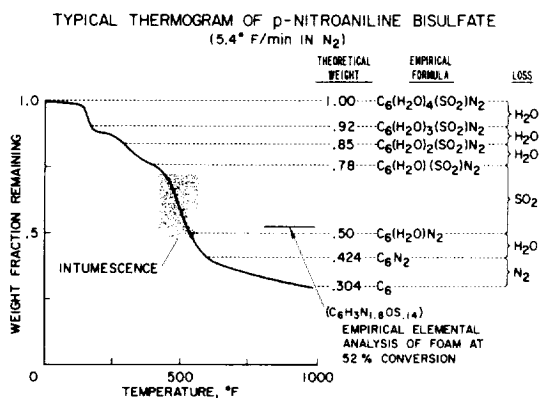
SYNTHESIS AND CHARACTERIZATION OF INTUMESCENT INTERMEDIATE



Synthesis and properties of appropriate derivative of p-nitroaniline for an intumescent intermediate.

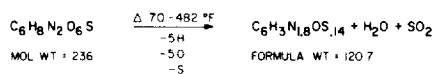


Gas chromatogram of principal gaseous species produced during intumescence of p-nitroaniline bisulfate.



Thermogram showing the consecutive thermochemical steps in the formation of the foam and vapor species during intumescence.

STOICHIOMETRIC REACTION OF p-NITROANILINE BISULFATE  
 EMPIRICAL FORMULA = C<sub>6</sub>H<sub>8</sub>N<sub>2</sub>O<sub>6</sub>S



THEORETICAL FOAM YIELD = 51.2 %  
 MEASURED FOAM YIELD = 51-54 %

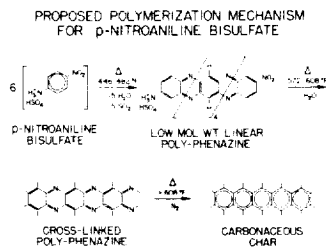
Outline of the overall thermochemical reaction for p-nitroaniline bisulfate.

EMPIRICAL ELEMENTAL ANALYSIS OF BLACK INTUMESCENT  
 POLYMERIC FOAM FORMED AT 482° F

ANALYZED FOR: (HSO<sub>4</sub>) NH<sub>3</sub> - C<sub>6</sub>H<sub>3</sub>N - (C<sub>6</sub>H<sub>2</sub>N<sub>2</sub>)<sub>4</sub> C<sub>6</sub>H<sub>3</sub>N NO<sub>2</sub>

	C	H	N	S	O
CALCULATED:	59.66	2.48	20.88	3.71	13.27
FOUND:	59.65	2.51	20.77	3.64	13.43

Structure and analysis for black foam produced by the intumescence of p-nitroaniline bisulfate.



The overall reactions leading to the production of thermally and oxidatively resistant polyphenazines (quinoxalines) derived from p-nitroaniline sulfate.

#### COMPOSITION OF INTUMESCENT COATING

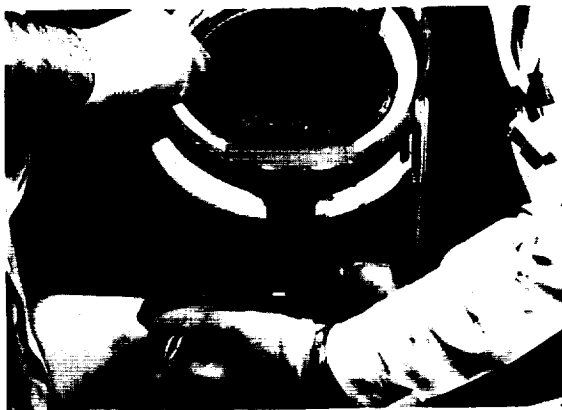
INGREDIENTS	WT. %
METHYL ETHYL KETONE	32.8
NITROCELLULOSE	6.9
p-NITROANILINE	27.5
ETHYL ALCOHOL	13.1
SULFURIC ACID	19.7

Ingredients and proportions for the intumescent paint. The paint is made as follows:

1. Mix p-nitroaniline with nitrocellulose/methyl ethyl ketone solution.
2. Add sulfuric acid/ethyl alcohol blend to form the intumescent salt.
3. Disperse in pebble mill for 20 hours.



ORIGINAL PAGE  
BLACK AND WHITE PHOTOGRAPH



Pebble-milling process used in blending ingredients of intumescent paint.



Comparison of pebble-mill and stir-in process. Paint on right prepared by stir-in technique. This sample has hard settling and short shelf life. Paint on left prepared by pebble milling. Paint is in excellent condition after three months.

#### TYPICAL PAINT PROPERTIES

NON-VOLATILES, WT %	54
DENSITY, g/cm <sup>3</sup>	1.09
VISCOSITY, BROOKFIELD, cps	1300
FINENESS OF GRIND, HEGEMAN	4 +
PIGMENT/BINDER RATIO, WT	6.9
P-NA/ACID RATIO, WT	1.4

#### TYPICAL COATING PROPERTIES

DENSITY ----- 1.36 g/cm<sup>3</sup> OR 85 lbs/ft<sup>3</sup>  
APPEARANCE ----- HARD, TOUGH, INTEGRAL COATING

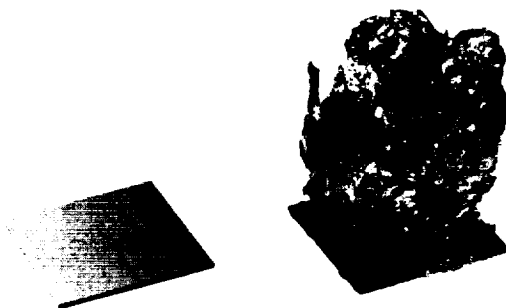
#### AFTER INTUMESCENCE

% WT LOSS ----- 54  
LINEAR EXPANSION ----- ~ 70 TIMES ORIGINAL THICKNESS  
DENSITY ----- 13 lbs/ft<sup>3</sup>

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BLACK AND WHITE PHOTOGRAPH



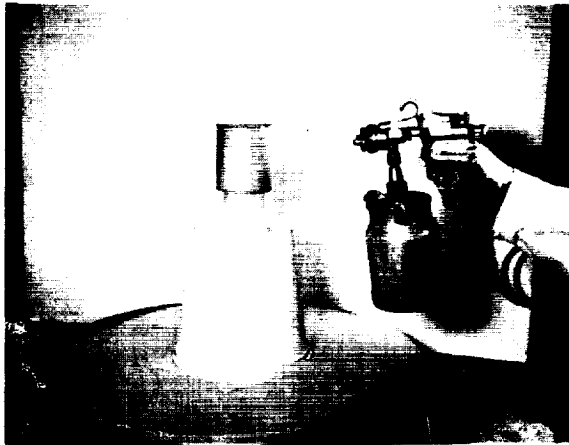
Taber abrasion resistance test of intumescent coating. The abrasion resistance of the intumescent paint is comparable to that of a commercial lacquer.



Coating before and after intumescence.

#### APPLICATION FEATURES

- TYPICAL SYSTEM
  - URETHANE SEALER COAT - INTUMESCENT COATING - NITROCELLULOSE TOP COAT
- CONVENTIONAL SPRAY EQUIPMENT
- TYPICAL THICKNESS OF 20 TO 60 mils
- CURES BY AIR DRYING
- TYPICAL SUBSTRATES
  - STEEL, ALUMINIUM
  - FIBERGLASS, CANVAS, WOOD, PLASTIC



Application of intumescent paint by means of a conventional suction-type spray.

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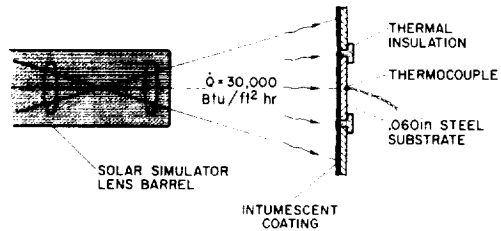
EFFECT OF SOME ENVIRONMENTS ON THE INTUMESCENT COATING  
 2"x2"x1/16" CR STEEL,  $ZnCrO_4$  PRIMER, NITROCELLULOSE TOP COAT

<u>TEST (24 hrs)</u>	<u>INTUMESCENCE</u>	<u>ADHESION</u>	<u>APPEARANCE</u>
WATER IMMERSION	NONE	NONE	NONE
SEA WATER IMMERSION	NONE	NONE	NONE
JP-4 FUEL IMMERSION	NONE	NONE	NONE
HUMIDITY, 93% RH 97° F	SLIGHT RETARDATION	PARTIAL LIFTING	SLIGHT DARKENING
OVEN, 120° F	NONE	NONE	NONE

PROJECTED COATINGS DEVELOPMENT

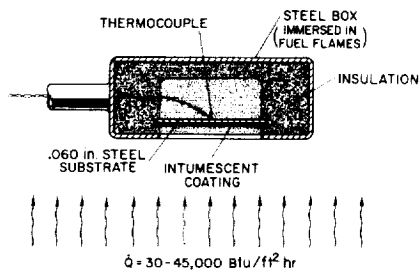
- CONTINUE EVALUATION OF OTHER BINDERS AND MODIFIERS
- CHARACTERIZE FORMULATION, PROCESSING, AND APPLICATION VARIABLES
- ESTABLISH SPECIFICATIONS
- DETERMINE LONG TERM PERFORMANCE OF COATINGS

ARRANGEMENT FOR TESTS OF INTUMESCENT COATINGS  
IN SOLAR SIMULATOR BEAM

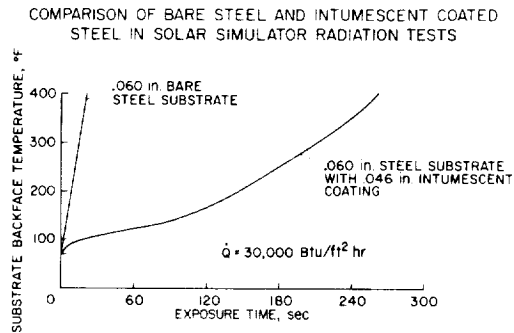


Test set-up used for screening of intumescent coatings. A solar simulator was used because heating from a fuel fire is mostly by radiation, and heating rate from simulator was easily controlled.

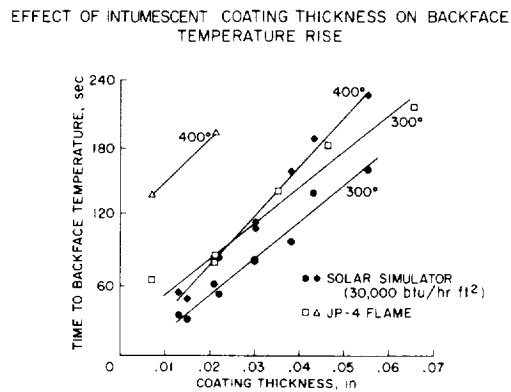
ARRANGEMENT FOR TESTS OF INTUMESCENT COATINGS  
IN JP-4 FUEL FIRE



Test set-up for screening of intumescent coatings in fuel fire. Heating rate approximately  $30,000 \text{ Btu/hr ft}^2$ . Test is terminated when substrate reaches  $400^\circ\text{F}$ .



After exposure to the solar simulator beam, tumescence begins within 10 seconds and is nearly complete within 20 seconds. The increasing slope beginning after about 80 seconds and continuing to termination of the test results from the higher heating rate experienced by the tumescence as it approaches the beam focus.



These results show the increase in protection obtained from an increase in coating thickness. The tests show that the solar simulator beam is unrealistically severe as compared with the fuel fire environment in which the intumescent coating is designed to survive.